Station Paper No. 123

June 1961

Yield of Unmanaged Slash Pine Stands in South Florida

by

O. Gordon Langdon

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance of the following cooperators and individuals: Robert E. Byrd, Leonard Greenwood, Harry Orwig, and Keith Pippin of the Atlantic Land and Improvement Company; Randall Specht, Virgil Davis, and Maynard Leetun of the American Agricultural Chemical Company; W. Kay Conard, Kenneth Arnold, L. B. Burnette, and Herman Spooner of the Collier Company; John Rogers of the Lee Tidewater Cypress Company; Robert Titus, George Reinert, Norman Lain, and Robert Kornegay of the Florida Forest Service; Rees Snedaker of Rayonier, Inc.; and Ellery A. Foster, consulting forester.

U.S. Department of Agriculture
Forest Service
Southeastern Forest Experiment Station
Asheville, North Carolina

COVER PHOTO

A 60-year unmanaged stand of South Florida slash pine.

Yield of Unmanaged Slash Pine Stands in South Florida

by

O. Gordon Langdon

Predictions of future timber yields are necessary for formulating management plans and for comparing timber growing with alternative land uses. One useful tool for making these predictions is a set of yield tables.

Timber growth and yield information for south Florida has been lacking; consequently, the forest productive potential has been largely an unknown quantity. Owners of the 7.9 million acres of commercial forest land in south Florida were necessarily forced to base management decisions of land use on very scanty forestry information. As young natural stands have become established and as general interest in forestry and tree planting has developed, the demand for growth and yield data has increased. This paper is published to fill this critical need until more complete data are collected for both managed and unmanaged stands.

STUDY PROCEDURE

The initial measurements of 90 permanent plots in a slash pine growth study provided the basic data used in compiling the tables and graphs contained in this report. These plots were established in stands varying in age from 8 to 61 years, in site index (based on age 25) from 30 to 77, and in stand density index from 26 to 321.

Field Work

Circular, $\frac{1}{4}$-acre plots were used with a 33-foot border strip having the same stand density as the plot itself. Pure, even-aged stands were required with not more than 25 percent of the stand composed of other species. Trees had to be evenly distributed before an area was selected for a plot; stands with appreciable clustering were not admitted. Stands could not show evidence of severe disease or insect attack or cutting within the past 5 years.

Measurements on the plot included a diameter tally and a crown classification of all trees. Height and age were obtained from sample trees selected from each diameter class. A height-diameter curve was drawn for each plot and used to determine the average tree height by diameter classes.

Study Areas

Plots were established in Collier, Hendry, Lee, Polk, Citrus, Hernando, Sumter, and Pasco Counties, Florida. Cooperators contributed land for the plots, help in locating and establishing the plots, and supervision in the cutting.

The topography of the study area is for the most part very flat, surface drainage is poor, and ground water levels are usually within 4 feet of the soil surface. Soils on the plots were classified in the following series: Broward, Charlotte, Felda, Immokalee, Keri, Leon, Ona, Pompano, and Sunniland; several others could not be classified.

Plot Summaries

Average plot age and total height were based on a sample of dominant and codominant trees. These averages were in turn used to determine site index from the curves derived as described in a later section. Measures of stand density, such as number of trees, basal area, and Reineke's (3) stand density index, were calculated.[1/] Reineke's curves were used in this study (fig. 1), and the relation of stand density index to average stand diameter, basal area, and number of trees per acre is shown in table 1.[2/] Average stand diameter was determined from the tree of average basal area.

Plot volumes in merchantable cubic feet and board feet ($\frac{1}{4}$-inch International Rule) per acre were calculated by 2-inch diameter classes for threshold diameters of 4.5 and 9.0 inches d.b.h. The volume tables for South Florida slash pine (1) were used to determine tree volumes (table 2).

Statistical Analysis

Multiple regression methods were used in the analysis of the plot data to determine the relation of the volume yield to stand age, site index, stand density index, and their interactions. The Schumacher (4) equation form for these yields was:

$$\text{Log } Y = b_o + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6$$

where, Log Y = Logarithm of yield in merchantable cubic feet or board feet

$$X_1 = \frac{1}{\text{Average stand age (A)}}$$

X_2 = Site index at age 25 (SI)

X_3 = Stand density index (SDI)

$X_4 = X_1 X_2$

$X_5 = X_1 X_3$

$X_6 = X_2 X_3$

b with subscripts = coefficients derived from the data

1/ Reineke's stand density index was used as a measure of stand density rather than basal area because a statistical test showed it to account for more variation. Other measures of stand density not tested might have served as well as the one chosen.

2/ All tables referred to in the text appear in the Appendix.

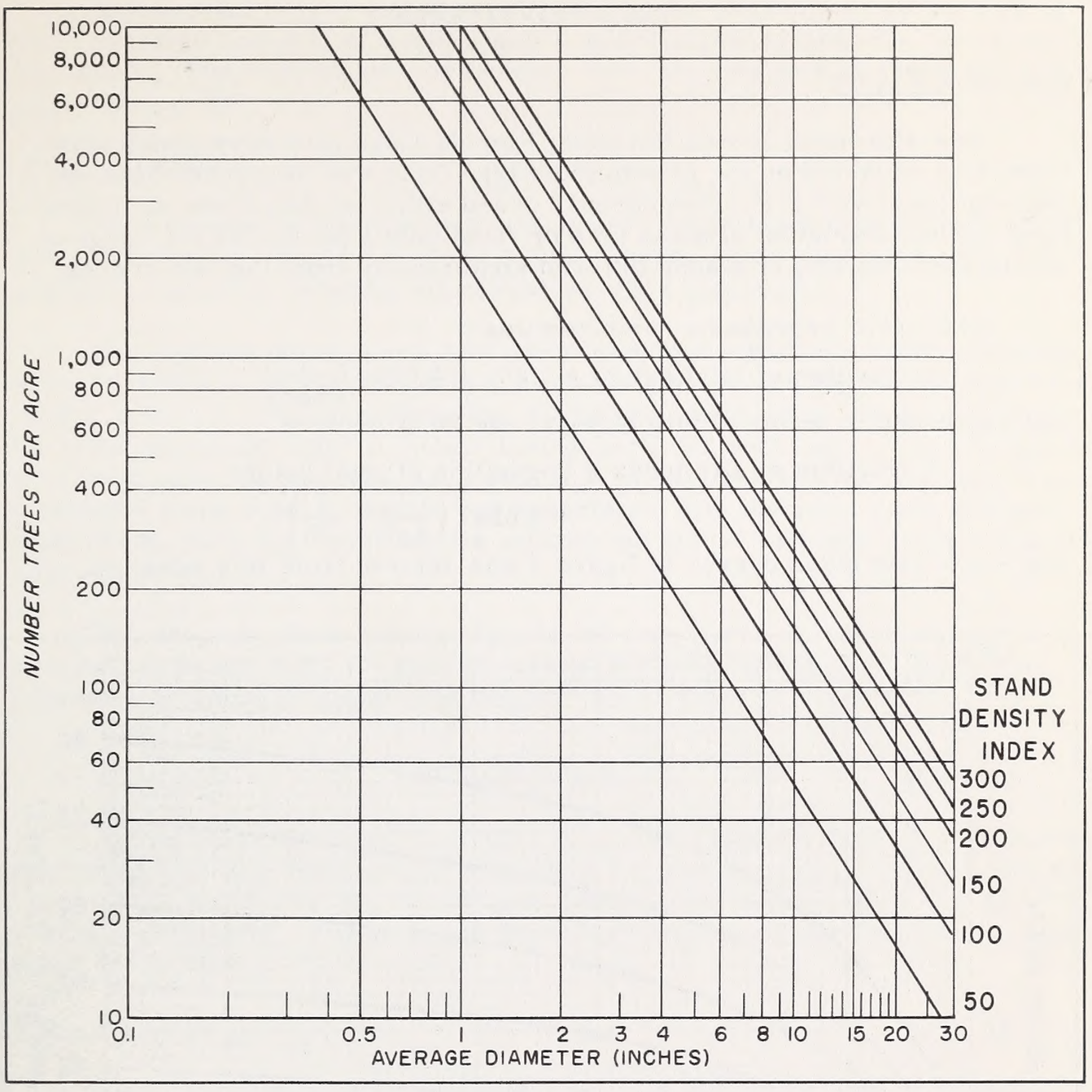

Figure 1.--Reineke's stand density index curves.

All possible combinations (63 in all) of regressions with the variables were not considered in this analysis. The selection and order of fitting the variables was determined by the contribution of the variables to the residual sum of squares. The variable that accounted for the most variation in a given step of the analysis was removed in that step. The variables in the four equations presented in this paper are listed in a descending order of fit. Curvilinearity was tested by plotting the residuals (Log Y - Log $\hat{Y}$) over each of the variables.

RELATED STUDIES

Site Index Curves

New site index curves for South Florida slash pine were constructed from data collected on the growth plots (2). This was necessary because existing slash pine site index curves, based either on data from the entire range of both varieties of slash pine or from only a portion of the range of the northern variety of slash, differed significantly from the new curves.

The linear regression computed was:

$$\text{Logarithm of total height} = 1.881 - 4.628 \left(\frac{1}{\text{Age}}\right)$$

and expressed in terms of site index at age 25 it became

$$\text{Logarithm of site index} = \text{Logarithm of total height} + 4.628 \left(\frac{1}{\text{Age}} - \frac{1}{25}\right)$$

The set of site index curves in figure 2 was derived from this equation.

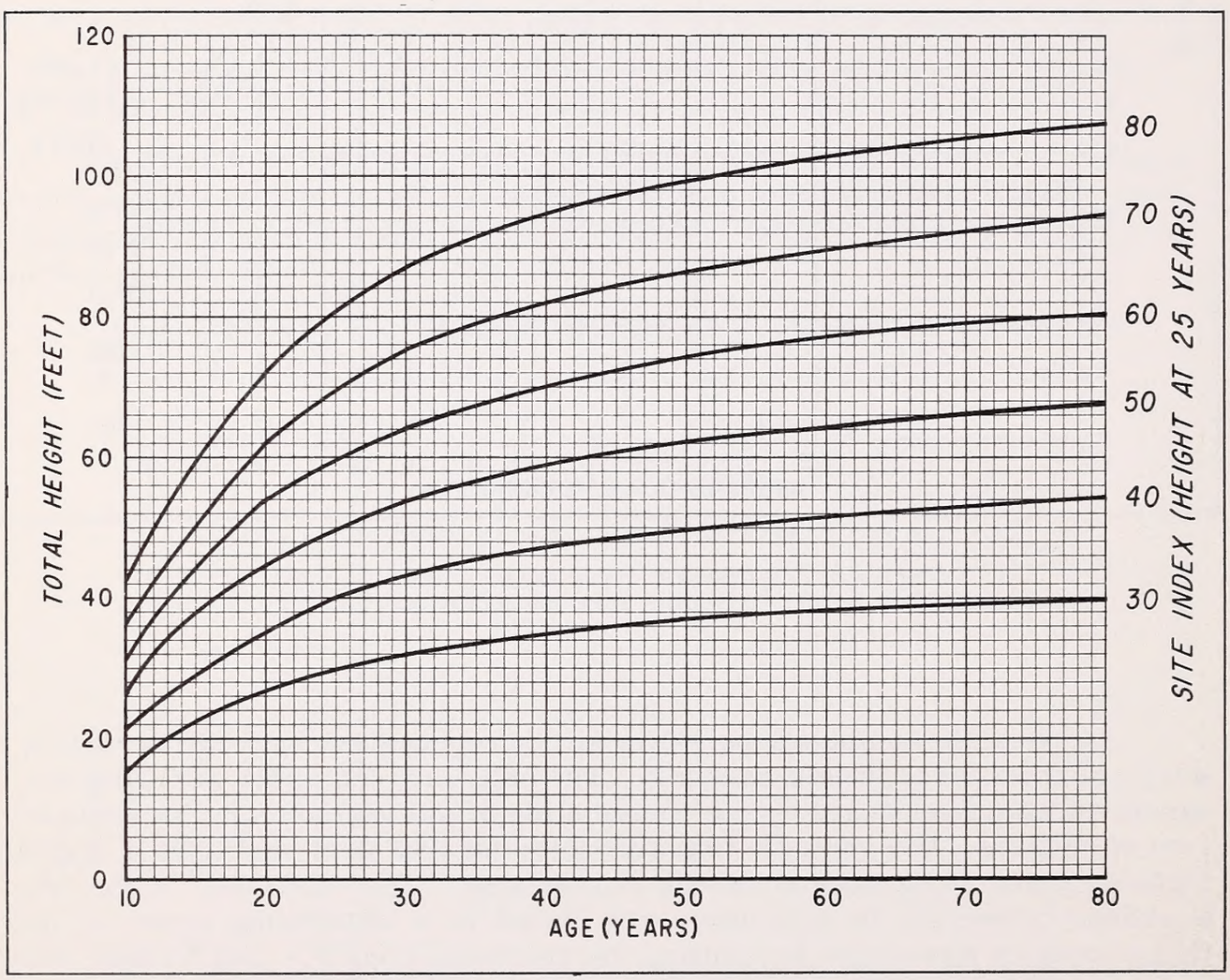

Figure 2.--Site index curves at index age of 25 years for slash pine in south Florida.

Independent height-age data collected by the Forest Survey from plots in 22 southern counties of south Florida were tested against the data from this study. The regression coefficients from the two sets of data were not significantly different.

Volume Tables

New volume tables (tables 2 and 3) were compiled for use in this yield study (1) because tables based on South Florida slash pine data were not available and other existing volume tables were inaccurate.

The volume tables were developed from measurements of 51 pulpwood-size trees (4.5 to 10.9 inches d.b.h.) and 80 trees of saw-log size (9.0 to 22.4 inches d.b.h.). The minimum top diameter limits were 3.5 inches inside bark for pulpwood and 7.5 inches inside bark for saw logs. The minimum size for a saw-log tree was 9.0 inches d.b.h. with one 16-foot log. The trees measured were from a sample not associated with the yield plots and were selected to cover the range of site conditions, form, and tree sizes found in south Florida.

The volume tables were prepared by regression methods using the general formula: $V = b_0 + b_1 D^2 H$, where V = tree volume, D = diameter breast height, and H = total tree height.

STUDY RESULTS

Yields were computed for: (1) Total merchantable cubic-foot volume (including both pulpwood and/or saw logs); (2) saw log cubic-foot volume; and (3) saw log board-foot volume by the $\frac{1}{4}$-inch International Rule. A fourth analysis estimated average stand diameter from stand age, site index, and stand density index.

Yield and Growth

The prediction equation for total merchantable cubic-foot yield was:

$$\text{Log } \hat{Y}_1 = 3.70240 - 37.861 \left(\frac{1}{A}\right) + 0.38828 \left(\frac{SI}{A}\right) + 0.03337 \left(\frac{SDI}{A}\right) \qquad \text{(Equation 1)}$$

where $\text{Log } \hat{Y}_1$ = logarithm of yield in cubic feet outside bark for trees 4.5 inches d.b.h. and larger to a minimum top diameter limit of 3.5 inches inside bark.

The variables in this equation were all highly significant, and together accounted for 90.5 percent of the variation about the mean. The other variables tested did not significantly improve this yield estimate.

The regression showed that total merchantable yield varied with increasing age and with the ratios of site index to age and stand density index to age. These yields were tabulated for age, site index, and stand density index classes (table 4).

Total merchantable mean annual growth for merchantable cubic-foot volumes was computed from the yield prediction equation (table 5). Mean annual growth generally culminates later on poorer sites and for any one given site later in the lower stand densities.

Cubic- and board-foot equations were developed to determine the yield of the saw-log portion of the stand. These equations showed that yields of saw-log material increase with decreasing stand density. This apparent paradox, although reasonable for stands with an average diameter below the 9-inch threshold, is not compatible with the growth of stands whose average diameters are well above this threshold. Therefore, these equations are not presented, but instead two tables (tables 6 and 7) are included using the average stocking encountered in this study (stand density index class 200). Table 6 shows the proportion of the merchantable yield in saw-log sizes, and table 7 shows the board-foot yields.

The board-foot:cubic-foot ratio of the saw-log volume was calculated (fig. 3), and is useful in comparing sawtimber and pulpwood stumpage values.

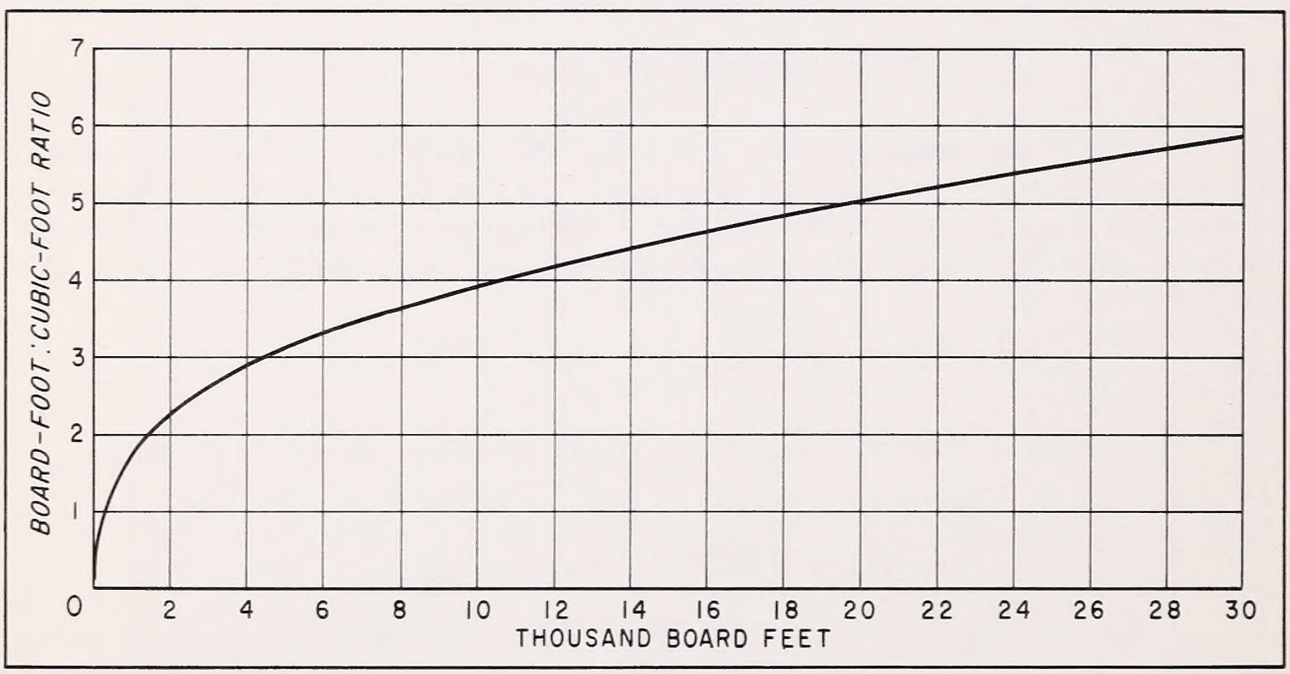

Figure 3.--Freehand curve showing board-foot:cubic-foot ratio by stand volume in board feet.

Average Stand Diameter

The effects of age, site index, and stand density index on average stand diameter for unmanaged slash pine stands were examined, and the following regression expressing this relationship was derived:

$$\text{Log } \hat{Y}_4 = 6.50085 - 0.66896 \left(\frac{100}{A}\right) + 1.02364 \left(\frac{SI}{10}\right) - 1.13411 \left(\frac{SDI}{100}\right) \qquad \text{(Equation 2)}$$

where Log $\hat{Y}_4$ = average stand diameter in inches at breast height.

All of these variables were highly significant and together accounted for 72.6 percent of the total variation about the mean. Table 8 shows the tabulated results that were computed from the above equation.

Southeastern Forest Experiment Station
P. O. Box 2570, Asheville, N. C.

ERRATA

Station Paper 123, "Yield of Unmanaged Slash Pine Stands in South Florida" by O. Gordon Langdon.

Page 7, line 4, Equation 2--Delete "Log," to read:

$$\hat{Y}_4 = 6.50085 - 0.66896\left(\frac{100}{A}\right) + 1.02364\left(\frac{SI}{10}\right) - 1.13411\left(\frac{SDI}{100}\right) \qquad \text{(Equation 2)}$$

Line 6 should read:

where $\hat{Y}_4$ = average stand diameter in inches at breast height.

Appendix

USE OF TABLES AND FIGURES

The tables and figures contained in this paper may be used to estimate stand volume, size, and condition. For example, a 40-year-old stand on a site index of 50 with a stand density index of 200 would, according to the estimates contained in the cited tables and figures, have the following characteristics on a per-acre basis:

Characteristics	Table
Total merchantable cubic-foot volume--2560 cubic feet	4
Mean annual growth--64 cubic feet at 40 years of age	5
Proportion of merchantable stand volume in saw-log sizes--40 percent, or 1024 cubic feet in saw-log volume	6
Board-foot volume--2820 board feet	7
Average stand diameter--7.7 inches d.b.h.	8
Number of trees--310	1
Basal area--99 square feet	1
	Figure
Average height of dominant and codominant--59 feet	2
Board-foot:cubic-foot ratio--2.5	3

Table 1. --Relation of stand density index to average stand diameter, trees per acre, and basal area per acre

Stand density index	Average stand d. b. h.	Trees per acre	Basal area per acre
	Inches	Number	Square feet
100	5	305	42
	6	230	45
	7	180	48
	8	145	51
	9	120	53
	10	100	55
150	5	450	61
	6	340	67
	7	265	71
	8	214	75
	9	178	79
	10	150	82
200	5	600	82
	6	450	88
	7	360	96
	8	290	101
	9	240	106
	10	200	109
250	5	760	104
	6	570	112
	7	445	119
	8	360	126
	9	295	130
	10	250	136
300	5	900	123
	6	680	133
	7	525	140
	8	430	150
	9	355	157
	10	300	164

Table 2. --Merchantable cubic-foot volume, outside bark, for South Florida slash pine, by diameter and total tree height 1/

D. b. h. (Inches)	Total height (feet)												
	30	35	40	45	50	55	60	65	70	75	80	85	90
	Cubic feet												
5	1.69	2.05	2.40	2.76	3.11	3.47	3.82	4.17	4.53				
6	2.63	3.14	3.65	4.16	4.67	5.18	5.69	6.20	6.72				
7	3.73	4.43	5.13	5.82	6.52	7.21	7.91	8.61	9.30				
8	5.01	5.92	6.83	7.74	8.65	9.56	10.46	11.37	12.28				
9	6.46	7.61	8.76	9.91	11.06	12.21	13.36	14.51	15.66	16.81	17.96	19.11	20.26
10	8.08	9.50	10.92	12.34	13.76	15.18	16.60	18.02	19.44	20.86	22.28	23.70	25.12
11			13.59	15.18	16.78	18.38	19.98	21.57	23.17	24.77	26.37	27.96	29.56
12			16.02	17.92	19.82	21.72	23.62	25.52	27.42	29.32	31.22	33.12	35.02
13			18.66	20.89	23.12	25.35	27.58	29.81	32.04	34.27	36.50	38.73	40.96
14			21.51	24.09	26.68	29.27	31.86	34.44	37.03	39.62	42.21	44.79	47.38
15			24.57	27.54	30.51	33.48	36.45	39.42	42.39	45.36	48.33	51.30	54.27
16				31.22	34.60	37.98	41.36	44.74	48.12	51.50	54.88	58.26	61.64
17				35.14	38.96	42.77	46.59	50.40	54.22	58.03	61.85	65.66	69.48
18				39.30	43.58	47.85	52.13	56.41	60.69	64.96	69.24	73.52	77.79
19				43.70	48.46	53.23	57.99	62.76	67.52	72.29	77.05	81.82	86.58
20					53.61	58.89	64.17	69.45	74.73	80.01	85.29	90.57	95.85
21					59.02	64.84	70.66	76.49	82.31	88.13	93.95	99.77	105.59
22					64.70	71.09	77.48	83.86	90.25	96.64	103.03	109.42	115.81

1/ Tabular values for the 5- to 10-inch d. b. h. classes from equation:

$V = 0.00284\ D^2\ H - 0.44$; standard error of mean = ± 0.11 cu. ft. or ± 1.19 percent; Coefficient of determination = 98.37 percent.

Tabular values for the 11- to 22-inch d. b. h. classes from equation:

$V = 0.00264\ D^2\ H + 0.81$; standard error of mean = ± 0.38 cu. ft. or ± 0.97 percent; Coefficient of determination = 97.70 percent.

Table 3. --Board-foot volume ($\frac{1}{4}$-inch International Rule) for South Florida slash pine, by diameter and total tree height 1/

D. b. h. (Inches)	Total height (feet)										
	40	45	50	55	60	65	70	75	80	85	90
	Board feet										
9	--	6	13	20	27	34	41	48	55	62	69
10	12	21	30	38	47	55	64	72	81	89	98
11	27	37	47	58	68	78	89	99	110	120	130
12	42	55	67	79	92	104	116	129	141	153	166
13	60	74	88	103	117	132	146	161	175	190	204
14	78	95	112	128	145	162	179	195	212	229	246
15	98	117	136	156	175	194	213	233	252	271	290
16	119	141	163	185	207	229	250	272	294	316	338
17	142	166	191	216	241	265	290	315	339	364	389
18	166	193	221	249	276	304	332	360	387	415	443
19	191	222	253	284	314	345	376	407	438	469	500
20	218	252	286	320	354	389	423	457	491	525	560
21	246	283	321	359	396	434	472	510	547	585	623
22	275	316	358	399	441	482	523	565	606	647	689

1/ Tabular values from equation: $V = 0.0171\ D^2\ H - 56.0$; standard error of mean = ± 2.5 bd. ft. or ± 1.29 percent; coefficient of determination = 97.63 percent.

Table 4. --Merchantable [1/] cubic-foot volume yields [2/] for slash pine stands in south Florida

Site index (Age 25)	Stand density index	Age (years)									
		15	20	25	30	35	40	45	50	55	60
		Cubic feet per acre (o.b.)									
30	100	150	360	610	880	1120	1350	1560	1760	1930	2100
	150	190	440	720	990	1250	1490	1700	1900	2070	2230
	200	250	530	830	1120	1390	1640	1850	2050	2220	2380
	250	320	640	970	1280	1560	1800	2020	2210	2380	2540
	300	420	780	1130	1450	1740	1980	2200	2390	2560	2710
40	100	270	570	880	1160	1440	1690	1910	2100	2280	2430
	150	350	690	1020	1320	1610	1860	2080	2270	2440	2590
	200	460	830	1190	1500	1800	2050	2260	2450	2620	2760
	250	590	1010	1390	1700	2010	2250	2460	2650	2810	2950
	300	760	1220	1620	1930	2240	2480	2680	2860	3010	3140
50	100	500	880	1250	1580	1860	2110	2330	2510	2680	2820
	150	640	1070	1460	1800	2080	2320	2530	2710	2870	3010
	200	830	1300	1700	2040	2320	2560	2760	2930	3080	3210
	250	1070	1580	1990	2320	2590	2820	3000	3160	3300	3420
	300	1380	1910	2320	2640	2890	3100	3270	3420	3540	3650
60	100	900	1380	1790	2130	2410	2640	2840	3000	3150	3240
	150	1160	1680	2090	2420	2690	2910	3090	3240	3380	3460
	200	1500	2030	2440	2750	3000	3200	3370	3500	3620	3690
	250	1940	2460	2840	3130	3350	3520	3670	3780	3880	3930
	300	2500	2980	3310	3550	3740	3880	3990	4090	4160	4190
70	100	1630	2160	2560	2870	3110	3300	3460	3590	3710	3800
	150	2110	2620	2990	3260	3470	3640	3770	3880	3970	4050
	200	2720	3180	3480	3700	3870	4000	4100	4190	4260	4320
	250	3520	3850	4060	4210	4320	4400	4470	4520	4570	4610
	300	4550	4660	4740	4790	4820	4850	4870	4890	4900	4910

1/ Includes merchantable cubic-foot volume of all trees 4.5 inches d.b.h. and larger to a top diameter of 3.5 inches inside bark.

2/ Tabular values from equation 1.

Table 5. --Mean annual growth[1/] for slash pine stands in south Florida

Site index (Age 25)	Stand density index	Age (years)									
		15	20	25	30	35	40	45	50	55	60
		Cubic feet per acre (o.b.)									
30	100	10	18	25	29	32	34	35	35	35	35
	150	13	22	29	33	36	37	38	38	38	37
	200	17	27	33	38	40	41	41	41	40	40
	250	22	32	39	43	44	45	45	44	43	42
	300	28	39	45	48	50	50	49	48	47	45
40	100	18	28	35	39	41	42	42	42	41	41
	150	24	34	41	44	46	47	46	45	44	43
	200	30	42	48	50	51	51	50	49	48	46
	250	39	50	56	57	57	56	55	53	51	49
	300	51	61	65	64	64	62	60	57	55	52
50	100	33	44	50	53	53	53	52	50	49	47
	150	43	54	58	60	60	58	56	54	52	50
	200	55	65	68	68	66	64	61	59	56	54
	250	71	79	80	77	74	70	67	63	60	57
	300	92	95	93	88	83	78	73	68	64	61
60	100	60	69	72	71	69	66	63	60	57	54
	150	78	84	84	81	77	73	69	65	61	58
	200	100	102	98	92	86	80	75	70	66	61
	250	129	123	114	104	96	88	82	76	71	66
	300	167	149	133	118	107	97	89	82	76	70
70	100	109	108	103	96	89	83	77	72	67	63
	150	141	131	120	109	99	91	84	78	72	68
	200	182	159	139	124	111	100	91	84	78	72
	250	235	193	163	140	124	110	99	91	83	77
	300	303	233	190	160	138	121	108	98	89	82

1/ Includes merchantable cubic-foot volume of all trees 4.5 inches d.b.h. and larger to a top diameter of 3.5 inches inside bark. Computed from data in table 4.

Table 6. --Proportion of merchantable stand volume in saw log sizes[1/] for slash pine in south Florida

Site index (Age 25)	Stand density index	Age (years)									
		15	20	25	30	35	40	45	50	55	60
		Percent									
30	200	1	2	5	8	11	14	17	20	23	25
40	200	2	5	9	15	19	24	28	31	36	39
50	200	4	11	19	26	33	40	46	51	56	61
60	200	11	25	37	48	58	67	75	82	89	90
70	200	27	54	74	88	100	100	100	100	100	100

1/ The minimum saw-log size tree was 9.0 inches d.b.h. with one 16-foot log.

Table 7. --Board-foot yields for slash pine stands in south Florida[1/]

Site index (Age 25)	Stand density index	Age (years)									
		15	20	25	30	35	40	45	50	55	60
		Board feet per acre ($\frac{1}{4}$-inch International Rule)									
30	200	--	10	50	110	200	320	460	620	780	950
40	200	10	60	170	370	640	950	1,310	1,680	2,070	2,450
50	200	50	250	660	1,250	1,990	2,820	3,690	4,580	5,470	6,340
60	200	290	1,100	2,480	4,250	6,250	8,340	10,450	12,500	14,490	16,380
70	200	1,670	4,900	9,350	14,400	19,590	24,690	29,550	34,110	38,380	42,330

1/ The minimum saw-log size tree was 9.0 inches d.b.h. with one 16-foot log.

Table 8. --Average stand diameter breast height for slash pine stands in south Florida[1/]

Site index (Age 25)	Stand density index	Age (years)									
		15	20	25	30	35	40	45	50	55	60
		Inches									
30	100	4.0	5.1	5.8	6.2	6.5	6.8	7.0	7.1	7.2	7.3
	200	2.8	3.9	4.6	5.1	5.4	5.7	5.8	6.0	6.1	6.2
	300	1.7	2.8	3.5	3.9	4.3	4.5	4.7	4.9	5.0	5.1
40	100	5.0	6.0	6.8	7.2	7.6	7.8	8.0	8.1	8.2	8.3
	200	3.9	4.9	5.7	6.1	6.4	6.7	6.8	7.0	7.1	7.2
	300	2.7	3.8	4.5	4.9	5.3	5.5	5.7	5.9	6.0	6.1
50	100	6.0	7.1	7.8	8.2	8.6	8.8	9.0	9.1	9.3	9.3
	200	4.9	6.0	6.7	7.1	7.4	7.7	7.9	8.0	8.1	8.2
	300	3.8	4.9	5.5	6.0	6.3	6.6	6.7	6.9	7.0	7.0
60	100	7.1	8.1	8.8	9.3	9.6	9.8	10.0	10.2	10.3	10.4
	200	5.9	7.0	7.7	8.2	8.5	8.7	8.9	9.1	9.2	9.2
	300	4.8	5.9	6.6	7.0	7.3	7.6	7.8	7.9	8.0	8.1
70	100	8.1	9.2	9.9	10.3	10.6	10.8	11.1	11.2	11.3	11.4
	200	6.9	8.0	8.7	9.2	9.5	9.7	9.9	10.0	10.1	10.2
	300	5.8	6.9	7.6	8.0	8.4	8.6	8.8	8.9	9.1	9.2

1/ Tabular values from equation 2.

Agriculture - Asheville